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STUDIES OF FROST PENETRATION

BY HARRY U. FULLER*

[*Read May 23, 1940.*]

In the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION for 1936, there appeared an article on frost penetration which attempted to state some of the reasons why frost goes deeper in some years than in others. It was stated that experiments were to be carried on by the Portland Water District to learn something further about what was going on in the ground in the winter time. The present paper is a report of what was learned by those experiments.

Thermometers were installed at 6-in. intervals from 1 ft. below the surface to 6 ft. below in two series; one set in clay and one in gravel. The thermometers were read at intervals of about a week for a period of a year beginning in September 1935. At the end of the year, the thermometers were indicating practically the same values as at the beginning. They had gone through a twelve-month cycle, cooling down through the winter and warming up during the summer.

The snow was removed from the ground over the thermometers so that the results would reflect conditions in roads that are kept clear of snow by plows.

The information obtained from these buried thermometers has been tabulated and diagrams have been drawn showing what the temperatures were in the ground from the time the ground began to freeze on the surface to the time when the last of the frost melted.

Frost Penetration in Gravel. Figure 1 shows the frost line in gravel. From left to right, time is shown, and the heavy line records how deep the frost is each day. It was found that the temperature of the air acts more rapidly in gravel than in clay. A two-inch pipe is drawn to scale in a five-foot trench in all figures to show how near the frost came to the pipe.

The frost began to go down on November 27 and reached its

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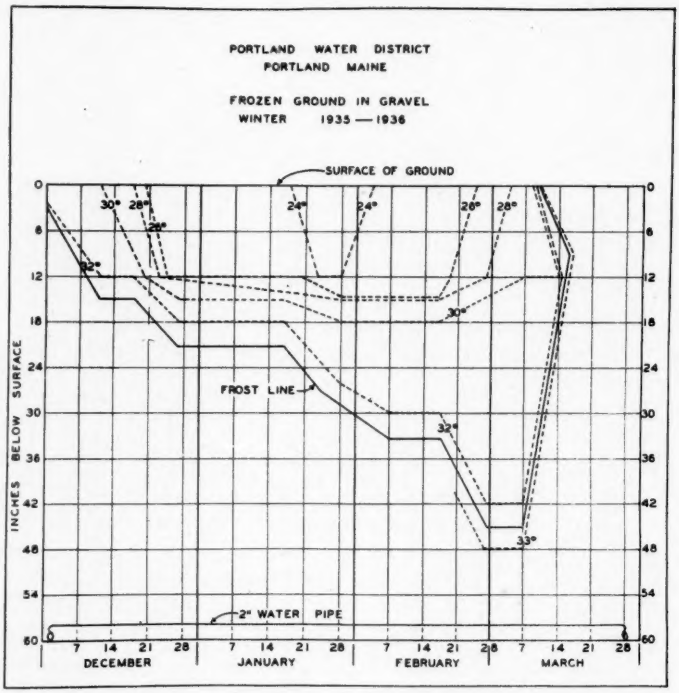

FIGURE 1.

lowest point on February 27. It held at its maximum depth of 45 in. until March 7, when the ground began to thaw at the bottom. On March 10, the surface began to thaw, and on March 16 the last frost melted only 15 in. below the surface. The dotted lines show the temperatures in the frozen ground, and it can be seen that in the last part of January, the ice reached a temperature of 24° F.

Frost Penetration in Clay. Figure 2 shows the frost line in clay. Beginning on December 15, the surface of the ground was frozen, and from that time until February 27 the frost line moved down 48 in. below the surface. From that time, it began to move upward, until on April 3 the last frost disappeared. The chart shows that on March 10 the surface of the ground began to thaw and continued thawing until on April 3 the last frost disappeared at a depth of 30 in. below

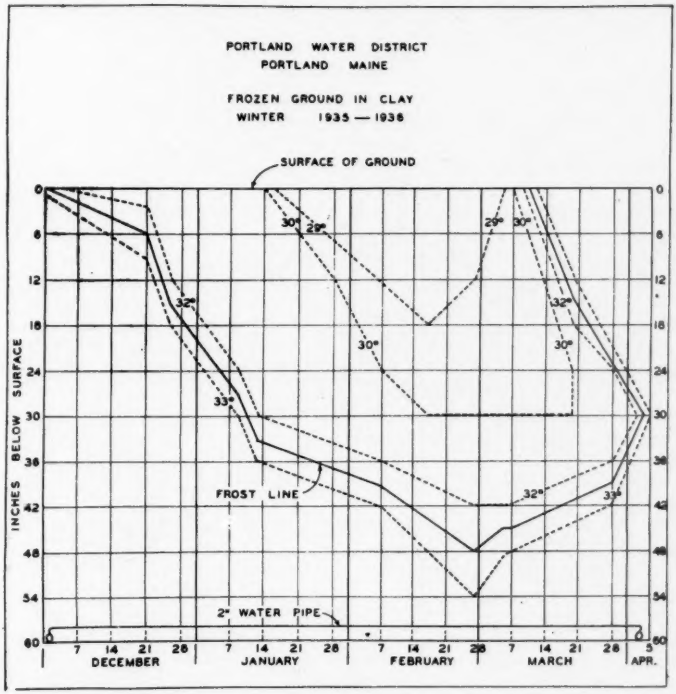

FIGURE 2.

the surface. The dotted lines show that the frozen ground reached and held a temperature of 29° F. during a large part of January and February.

Combination Frost Line. Figure 3 gives the frost line in both gravel and clay. It shows how much more responsive to the temperature of the air is the gravel than the clay. The frost went down more rapidly in the gravel than in the clay until about the first of the year; then the line for clay overtook the line for gravel and proceeded more rapidly than the other. On March 1, they were both at the same depth and kept together for about a week. Then under the influence of the increasing daily temperature the frost went out of the gravel in a week, while a month was required to melt all the frost in the clay.

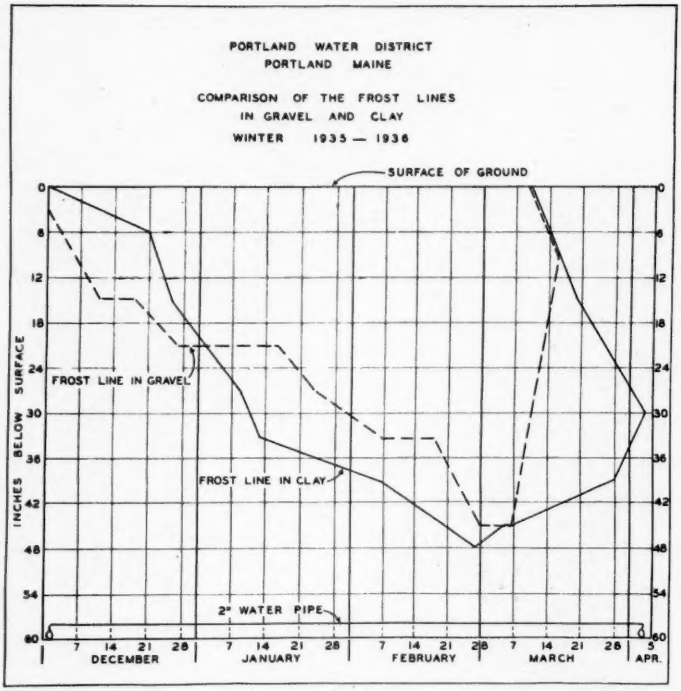

FIGURE 3.

Accumulated Deficiency Curve. Each day the newspapers in the report of the Weather Bureau tell the mean temperature for the preceding day. If this information is not easily obtained, a thermometer can be read early in the morning and in the evening. The average of these readings is not far from the mean temperature. When the season is advanced to where the mean temperature is less than 32° F. the ground begins to freeze. If the mean temperature for the day is subtracted from 32° F., the difference is a measure of the freezing effect of the air on the ground. If this deficiency of temperature below 32° F. is added each day to that of the preceding days and the result plotted on cross section paper, a mass curve is obtained, which is a measure of the severity of the winter.

Relationship Between Air Temperature and Frost. Figure 4

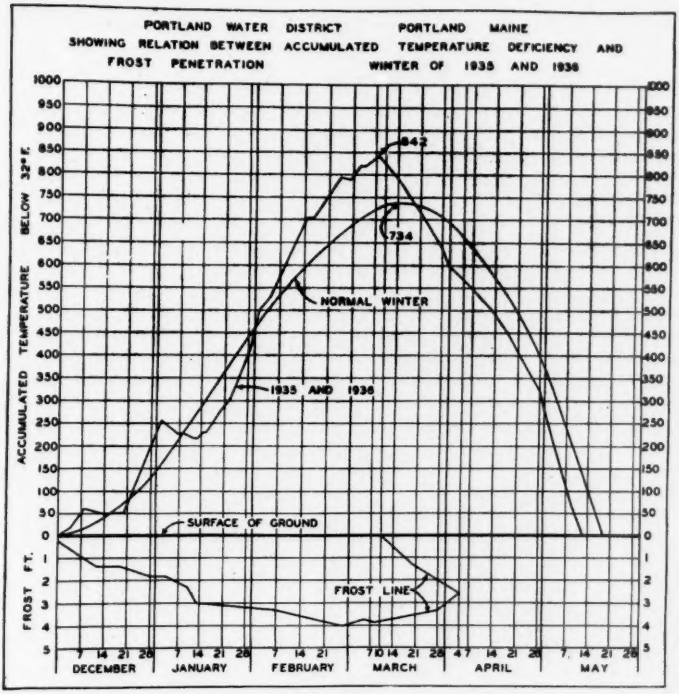

FIGURE 4.

frost line for the winter of 1935-36. It also shows the average accumulated deficiency curve at Portland for fifty years. The winter shown was not far from a normal winter and the accumulated deficiency reached 840 degrees before beginning to go down.

The frost line in this diagram is a combination of the gravel and clay lines from the previous diagrams and is the lower at each point. It can be seen that as the temperature deficiency line rises, the frost line goes down, and in gravel, when the weather moderates and the deficiency line runs level, the frost line also tends to run level. There is some lag between cause and effect in all parts of this diagram, and the clay is much less responsive to quick changes in air temperature than is the gravel. On this diagram, it takes about one-half as long for the frost to leave the ground as it did for it to go down to

the low point. There seems to be a very good relation between the frost line and the temperature deficiency line while the frost is going down, but when the air above as well as the ground beneath are both melting the frost, the relationship is not so good.

Range in the Severity of Winters. In the winter of 1917-18, the accumulated deficiency reached a high point of 1500 degrees, while in the winter of 1936-37, the high point was 170 degrees. In the

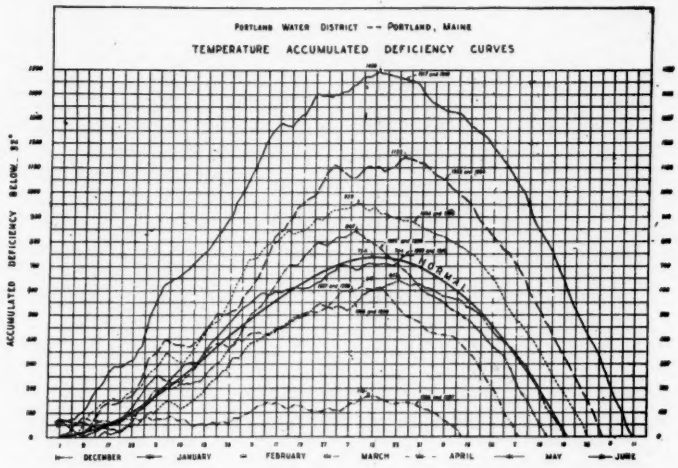

FIGURE 5.

former year, the frost was not out of the ground until about May 1, while in the latter year it was out about April 1. The other years studied have varied between these extremes.

Loose unpacked snow is well known to be an excellent insulator, but in these days of automobiles, when snow plows keep the ground nearly bare and the traffic soon packs the remaining snow to the condition of ice, the insulating properties of the snow are not effective in the roads.

Frost Chart. From the experiments that have been described and records of when the frost was virtually out of the ground on previous years, a chart has been prepared on which the accumulated deficiency line can be plotted (Fig. 6). The depth of frost can be read on this chart by observing the point at which the temperature

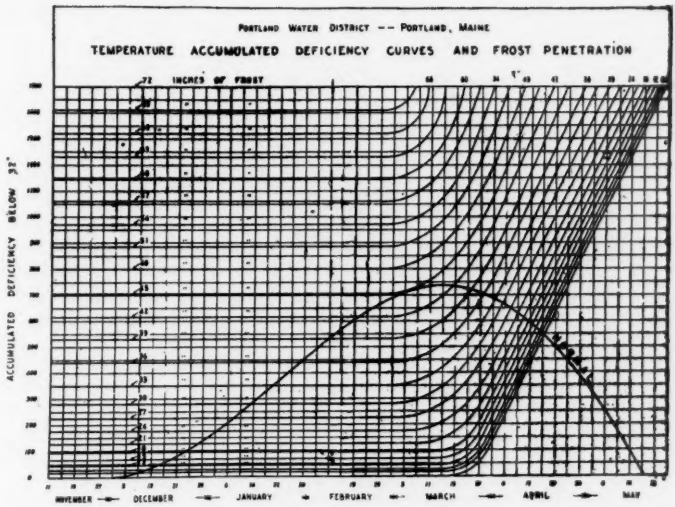

FIGURE 6.

line crosses the various dashed lines which are marked to indicate the depth of frost at that particular point. This frost chart has been in use in Portland during the past winter and has worked very well.

A record was kept of the depth of frost found as the season progressed, and the dashed lines were a fair average, but there was more frost in some places and less in others, as was to be expected, in the different kinds of soil. The chart indicated that the frost would be gone by about April 15. It was found that such was the case, except for a few shady places. The effort required to make the chart has been found worth while by a number of water works operators.

THE STORY OF P.W.A. IN MAINE WATER WORKS

BY F. J. RENY*

[*Read May 23, 1940.*]

A description of the work done under the Federal Works Administration (P.W.A.) should perhaps be preceded by a short résumé of the plan designed by this Administration to aid the construction of water utility projects by the United States Government. At the time of inception of the idea, it was thought by water utilities officials that work under governmental supervision could only be done with a great deal of red tape and with great additional expenses and that, in all probability, the grant would be taken up by the additional amount of supervision and other details which would be necessary under governmental work. Many utilities hesitated before taking advantage of these privileges which the government held out in the way of grants in a water works construction project and it was only after considerable consideration that our own utility officials were in accordance with the request for a governmental grant to construct a water project.

The governmental plan provided that, in the event a project was sponsored, the whole amount of the estimated cost of the project could be estimated by the engineers, broken down into the various items of data, supporting the grant application, which are roughly:

A general description, together with estimated preliminary expenses.
Costs of land and rights of way.
Costs in detail, showing breakdown.
Engineering, architectural, and other technical services.
Estimated administrative and overhead costs.
Interest during construction.
Miscellaneous cost of all kinds together with a total of the estimated cost of the project.

All of this detail, broken down into various divisions of man hours of skilled, unskilled, intermediate, technical and clerical labor, together with a description of the estimated amount of material and

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the average number of employees per month, made a rather formidable document to prepare, where small utilities, particularly, had no advisory board and were obliged to go to the engineer to get the applications in the proper shape. After the estimate was made of the total cost, the amount of the grant was to be 45% of the total estimated cost. This amount to be made partially available in the amount of 25% upon certain completions of the work. This was, roughly, a description of the application to be made in the event that a project was desired.

Truthfully, we can say, after our experience with P.W.A., that the bugaboo of governmental red tape was satisfactorily dissipated. The valuable assistance given us by the Regional Engineer Inspector in charge, Mr. Feeney and his predecessor, Mr. Mullaney, is hereby acknowledged. There was certainly nothing that could be done in the way of aid that was not cheerfully done by these men and their assistants in all of our projects.

A description of the work accomplished by the Portland Water District under P.W.A. Projects is interesting. The first application submitted by the Portland Water District to the Administration was in 1936 and consisted of laying approximately 20,000 ft. of 8-in. cast-iron pipe in the town of Falmouth. The work was let out to the contractor, John McDonald Company of Newton, Mass., in April 1936 and was completed in November of 1936. This was our first experience with P.W.A. and gave us the necessary education so that we were able to decide whether the grant of 45% was of any material value to us in the completion of a water works job.

Difficulties were encountered in the labor situation, and it was found that suitable labor was not to be procured from the U. S. Employment Bureaus, nor from the unemployed on the City Relief Rolls. The contractor did his best to work with the men assigned from these departments, but they simply did not have the ability to cope with ledge work, and it was found necessary by the contractor to put machinery on for excavating ledge. The work was completed, however, in time and the total cost of the project was $87,316.41 and the P.W.A. grant amounted to $35,066.41.

In the recapitulation of this project, it was found that at least 25 or 30% of saving had been accomplished by the letting out of a job to a contractor and that the red tape consisted principally of paying the expenses of an inspector on the job, for which we were

not allowed, nor for interest during construction. This, however, was not so important and so we made no protest.

The Portland Water District Trustees decided later in 1938, on account of the fact that money could be borrowed at such a low rate and a bond issue had been made for 2¼%, which would finance the work in mind, to proceed to make other applications to P.W.A. as follows:

For the installation of approximately 38,000 ft. of 48-in. cast-iron or reinforced-concrete pipe to be installed from the end of the 48-in. line, which was laid in 1931, to the Chlorine house at Sebago Lake.

This work had been originally planned by the engineers to be partially done in 1942 and 1945 in separate sections, but on account of the low interest rates and the 45% grant, it was decided that it would be efficient to do the work at this time, even though it might be in advance of the time set by the engineers, as this would complete the system of dual mains. Therefore, bids were advertised for this work, and the low bidders were the Lock Joint Pipe Company of Ampere, New Jersey, in the amount of $573,310 for reinforced-concrete pipe. This bid also included approximately 4500 ft. of 30-in. pipe to connect with the existing distribution system. The total estimated cost of the project, when submitted, was $832,341; the work to commence October 31, 1938 and to be finished before October 5, 1939.

These bids being acceptable to the Public Works Administration, we were notified to proceed immediately, and the contractor set up plant to manufacture pipe at Westbrook in the same location where the pipe had been made for the same type of construction in 1931, when a portion of this main had been laid. The work was carried along with speed, and the pipe was made and transported to the trench locations during the winter. When the ground was ready in the spring, the pipe was installed in the trenches and 7 miles of 48-in. and 30-in. pipe were in place and completed in October of 1939 and the water turned on.

The addition of the job of remodeling the Chlorine building added $6,300 more to this contract and caused the time of total completion to be set ahead for a month. The completed project shows that although the contract price for the installation of the 48-in. main was $573,000 and the addition of the Chlorine station, $6,300 more, the total cost of the project will run well over $600,000, when the land,

legal and other expenses are added. The total final audit has not yet been completed, but it is probable that the total contribution from the P.W.A. will be approximately $270,000 and the District's cost, $330,000.

The second P.W.A. Project submitted at nearly the same time to the Administration was made principally in order to improve fire service in certain sections to comply with the suggestions of the National Board of Fire Underwriters. Investigation had disclosed that various dead ends in Westbrook and West Falmouth should be connected to give satisfactory fire service and supply, and this called for a new standpipe to be installed on the heights on Brook Street, in Westbrook with a capacity of 250,000 gal. Other small mains in the Deering section were replaced by 16-in. and 12-in pipe, and five hydrants were added at certain points. This project was submitted to the Administration in the amount of $198,800. Bids were called for, and the successful bidder was the Camillo Profenno Company of Portland, with a bid of $134,141; the work to be started on December 1, 1938 and to be completed before July 10, 1939. The Profenno Company immediately started construction on that day, and the work was completed well within the time specified. The total cost of the project was $142,692.03 and a Public Works Administration grant was received in the amount of $64,213.21.

A recapitulation of these projects shows that the Portland Water District has completed three Public Works Administration Projects and has received grants from the United States Government as follows:

Project One:	Total cost	$ 87,316.41	Grant received	$ 35,066.41
Project Two:	Approximate total	600,000.00	Approximate grant	270,000.00
Project Three:	Total cost	142,692.03	Grant received	64,213.21
	Total costs	$830,008.44	Total grants	$369,279.62

These figures show that the Portland Water District Trustees have been very active in taking advantage of governmental assistance in the construction of necessary water works projects. Regardless of our belief in the policy of the government or not, we have to admit that as we are of necessity doomed to pay taxes upon the money which has been expended, whether in our own state or other states, that we might as well have the benefit of it in our own community and our own state, as to allow the money to be expended elsewhere. We have not received any criticism from our water takers nor from

any of our citizens residing in the section supplied by the Portland Water District. In fact, most every comment has been of congratulatory nature because we were able to foresee the advantage of constructing under these conditions.

Other projects, which have been constructed in the state include the following:

In the Bath Water District, a difficult underwater job of submarine pipe line was done under a P.W.A. Project at an estimated cost of $130,000.

In the Brunswick and Topsham Water District, water mains and a standpipe were constructed at an estimated cost of $150,000.

In Hampden, a new system was installed under P.W.A. at a cost of $131,000.

At North Haven, water works improvements were made to the amount of $6,000.

In Sanford, the Sanford Water District constructed improvements estimated at a cost of $35,000, with water pipe up to 16 in. in diameter and of various sizes installed, and another project aggregating $26,300 in the same town.

In Yarmouth, the Yarmouth Water District has installed 2700 ft. of 2-in. and 2,000 ft. of 10-in. pipe, as a P.W.A. Project, with a total contract of $12,770.

In York, new main and standpipe construction total approximately $115,000.

These projects, together with the work done in Portland, aggregate $1,783,300.

In addition, a water power development in the amount of $228,000 was installed at Lewiston making a grand total of $2,011,300.

It must be noted that the installation of these projects, all of which received 45% grants upon the cost, made a very noteworthy saving in the cost of this water work construction. Comment from the engineers in charge has borne out my statement that from 25 to 30% of the grant has been salvaged and that the governmental supervision has not cost what it was estimated it would. It is well borne out that Public Works Administration assistance proved to be so valuable after investigation that many localities were desirous of receiving assistance and submitted projects which were received by the Administration too late to be allowed.

The Portland Water District had submitted a project to supply

water to the towns of Sebago and Standish with a P.W.A. Project in the amount of $197,000, but due to some delays, for which we were not accountable, the request was received by the Administration too late and was denied.

There were also applications for works at Anson, Lubec, Alfred, Lisbon Falls, Presque Isle, Readfield, Rumford, Norway, Kingman, Locke Mills, and Casco. These projects were all received after the time when the money was available, and the applications were forced to be turned down, for the reason that the money had been apportioned to other places. These projects have been retained by the Administration in their records, and the applicants have been assured that in the event of more money being apportioned to P.W.A., they will receive consideration.

EXPERIENCES WITH CORROSION CONTROL AT BIDDEFORD, MAINE

BY EDWIN T. McDOWELL*

[*Read May 23, 1940.*]

The new purification plant of the Biddeford & Saco Water Co. was completed and put in service early in 1937. Its operation included the usual processes of coagulation with alum, sedimentation, and rapid sand filtration. Sterilization was accomplished by the use of liquid chlorine and later, by ammonia also. A small amount of soda ash was used to counteract to some extent the low pH of the finished water produced by the action of the alum used in the coagulation process.

In the old plant, which was abandoned in 1937, the same general procedure had been followed for a number of years, and a satisfactory water had been obtained, but this had been accomplished with difficulty because of the necessity of operating at a considerable overload. When the new plant was put in service, a decided improvement was immediately noticed in the water throughout the distribution system. We were producing a colorless, odorless water with no turbidity; in fact from a physical and bacteriological standpoint it left little to be desired. Apparently everybody was satisfied and pleased with the change until shortly after Labor Day 1937.

A considerable portion of our distribution system is used to supply local beaches and summer resorts. There is a very heavy demand for water during the summer months and a very small consumption, and consequently a slow circulation, during the winter. We had experienced some difficulty in these outlying sections during past winters due to colored water, but it had never been serious and was usually remedied by occasional flushing. In September, 1937, however, when the summer visitors had departed and the water consumption had decreased as usual, we began to receive complaints of colored water from people living in and near the summer resorts, and particularly from those who were served by some water mains that had been

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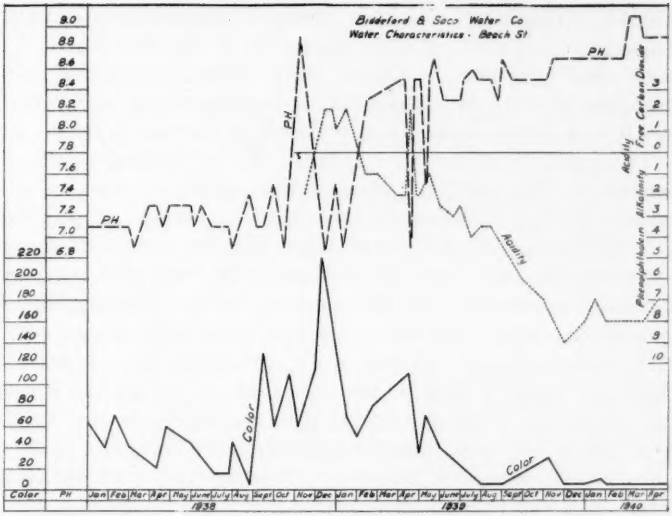

Biddeford & Saco Water Co
Water Characteristics - Beach St
PH
Acidity
Free Carbon Dioxide
Phenolphthalein Alkalinity
Color
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec Jan Feb Mar Apr
1938
1939
1940

cleaned about two years previously. In spite of frequent flushing, this condition persisted more or less all through the winter. During the following summer, when the consumption of water again increased, the color diminished and nearly disappeared; but in September, 1938, the unsatisfactory conditions returned in a more aggravated form.

It was apparent that the removal by the new filters of all the color and other impurities from the water had in some manner increased its corrosive activity, and we began experiments in search of some means to reduce this activity. The feeding of soda ash was stepped up and the pH of the filtered water gradually raised to about 7.5. This brought about some improvement, but it was evident that the treatment could not be carried much further, as the amount of soda ash required would be large and costly. Aside from this, the addition of large amounts of soda ash imparted an unpleasant, medicinal taste to the water and this was soon noticed by consumers.

It was decided therefore, to experiment with lime treatment in order to raise the pH to a still higher figure, and in October, 1938, this form of treatment was begun. We found lime to be much more efficient than soda ash for this purpose but also much more difficult

to control. Soda ash had a very uniform effect and, the variations in dosage always produced a corresponding change in the pH. Lime, however, had little effect up to a certain critical point, but as soon as this point was reached, the effect of additional lime was very pronounced and small increases or decreases brought about rather violent changes. The lime was applied to the filtered water just before it entered the clear well, and after a short period of experimentation during which rather wild results were produced, we succeeded in getting the treatment adjusted so that a very uniform water was obtained.

Another difficulty was encountered here, however, due to the formation of a secondary floc or precipitate in the filtered water after the lime was added. An examination of the accompanying table in which are shown the characteristics of the water as it comes from the source of supply and the changes which take place in it during the several phases of the purification process, will show that the Saco River water is very low in natural alkalinity. Averaging about 7.7, and occasionally dropping as low as 5.0, it was very difficult at times to secure a good floc, especially in cold weather. It was evident that the reaction of the alum was incomplete and that the addition of alkalinity in the form of lime in the clear well completed this reaction and formed a secondary floc in the filtered water which was, of course, undesirable.

Consequently, we decided to split the lime dosage and apply part of it at some point before the water reached the filters in order to complete the reaction and throw down the precipitate before the filtration process began. Subsequent experiments indicated that the location of the first application of lime was important. As a beginning, the lime was added to the raw water before the addition of alum. This improved the formation of the floc but had the effect of setting the color so that it was difficult to remove. The lime feeder was then moved to the outlet end of the coagulation basin so that lime was added after coagulation and settlement had taken place. As this did not prove satisfactory, the feeder was moved gradually back towards the inlet end of the basin with a noticeable improvement in coagulation. The best location was finally found to be near the outlet end of the baffle chambers where the mixing and agitation of the raw water and the alum solution is nearly completed and the primary floc is already formed. After the most advantageous location had been discovered, it required considerable time and experimentation to deter-

mine the proper amount of lime to use. We found that this was governed by no hard and fast rule and that the dosage had to be varied according to temperature, turbidity, color and other characteristics of the incoming water. As soon as the proper methods were arrived at and adjusted, however, the after-precipitation in the clear wells disappeared.

We have always assumed that temperature had a considerable effect upon the efficiency of alum as a coagulant. We had been led to expect, and indeed had experienced difficulty in securing good coagulation when the temperature of the raw water approached the freezing point, but our experiments with lime treatment did not bear out this theory. Provided the proper dosage of alum and the correct ratio of alum to lime was maintained, it was possible to secure practically as good a floc in the basin when the temperature of the water was 32° F. as when it was at its maximum during the summer months. But our experience demonstrated that the alum-lime ratio must be changed often to correspond with changes in the raw water and that a very close chemical control must be maintained.

As soon as the difficulty with after-precipitation in the filtered water had been overcome, the application of lime in the clear well was again increased. During this time, samples were taken frequently at one of the locations where the red water troubles were particularly severe and compared with similar samples drawn from the tap at the filtration plant. During the early days of the experiment, when the pH of the filtered water was being gradually increased, the pH of the water in the area being studied lagged considerably behind that at the plant. As time passed, this difference slowly diminished and finally disappeared. During the past few months, the pH at the point of sampling has tended to exceed that at the purification plant.

In order to demonstrate more clearly the effects of the lime treatment, the color, acidity and pH values at the point of sampling—which, incidentally, represent the extreme conditions which existed only at this location—have been plotted in the form of curves and these illustrate the changes that have taken place in the area under consideration over a period of 28 months. A study of the curves will reveal the close relationship that existed between these values, and it will be observed that changes in the pH and acidity were reflected in almost every instance by corresponding changes in the color. The

color curve remains roughly parallel to the acidity curve but the pH and color curve react in opposite directions. The zero line of the acidity curve has been drawn at pH 7.8 and it is interesting to note that the pH and acidity curves cross at about this point. Whenever the acidity curve rose above this zero line, high color usually appeared.

Free carbon dioxide, as shown by the acidity curve, finally disappeared in April, 1939, and since that time the color has gradually diminished until it reached a very low figure in August. In September, when our past experience led us to expect a violent change, the increase in color was only nominal. In November, the color had all but disappeared and has remained at a very low figure since that time.

Water Characteristics—Biddeford & Saco Water Co.

Month	Pumpage	Alum	Lime	Chlorine	Ammonia	Color		Turbidity		Soap Hardness		Alkalinity		pH				Acidity, CO_2			Phen. Alk.†	
1939	M.G.D.	G.P.G.*	G.P.G.*	P.P.M.	P.P.M.	Raw	Finished	Raw	Finished	Raw	Finished	Raw	Finished	Raw	Coagulated	Applied	Finished	Raw	Coagulated	Applied	Finished	Finished
Jan.	2.216	1.33	0.60	0.39	0.07	51	8.0	3.5	0	11	23	5.3	10.6	6.7	5.1	5.9	7.3	1.9	6.5	3.1		
Feb.	2.268	1.32	0.67	0.32	0.07	39	1.8	3.8	0	12	23	7.4	13.6	6.7	5.1	6.3	7.8	2.0	7.9	2.6	0	1.6
Mar.	2.205	1.37	0.71	0.35	0.09	53	1.0	9.9	0	12	22	7.1	13.4	6.5	5.1	6.4	8.0	2.1	7.7	1.8	0	1.7
Apr.	2.158	1.30	0.66	0.38	0.09	55	1.8	26.6	.06	12	24	6.7	12.1	6.4	5.1	6.5	8.0	1.9	7.8	1.6	0	1.8
May	2.373	1.25	0.70	0.39	0.08	48	1.0	5.4	0	12	26	5.5	12.2	6.5	5.0	6.5	8.5	1.9	8.1	1.8	0	3.1
June	2.313	0.99	0.53	0.41	0.08	41	0.2	4.5	0	10	22	7.8	13.1	6.7	5.2	6.3	8.3	2.0	6.3	2.4	0	2.6
July	2.926	0.75	0.45	0.41	0.08	37	0.5	7.6	0	10	20	8.7	13.9	6.9	5.3	6.2	8.5	2.0	5.1	3.0	0	3.1
Aug.	2.846	1.00	0.56	0.47	0.09	56	3.4	11.1	0.5	9	19	8.6	15.1	6.8	5.0	6.0	8.4	1.7	5.6	3.4	0	3.1
Sept.	2.083	0.96	0.51	0.36	0.10	30	0	3.8	0	9	21	9.4	15.2	6.9	5.1	6.2	8.5	1.2	4.6	2.6	0	3.3
Oct.	1.784	0.86	0.52	0.36	0.09	31	0	4.2	0	10	23	10.0	15.8	6.9	5.1	6.3	8.5	1.1	3.9	2.1	0	3.6
Nov.	1.785	1.46	0.78	0.43	0.11	55	2.3	12.6	0.3	9	26	7.9	15.5	6.7	4.7	5.8	8.4	1.9	8.9	3.3	0	3.7
Dec.	2.042	1.23	0.69	0.43	0.13	46	0.2	10.5	0	10	24	7.8	15.5	6.5	4.9	6.2	8.4	1.8	6.9	2.1	0	3.5
Aver.	2.250	1.15	0.62	0.39	0.09	45	1.7	8.8	0.07	10.5	23	7.7	13.9	6.7	5.1	6.2	8.2	1.8	6.6	2.5	0	2.8

*G.P.G. = Grains per gallon.
†Phenolphthalein Alkalinity.

MODERN ENGINEERING PRACTICE AND TWO-INCH CAST-IRON PRESSURE PIPE

BY C. D. COX*

[*Read May 23, 1940.*]

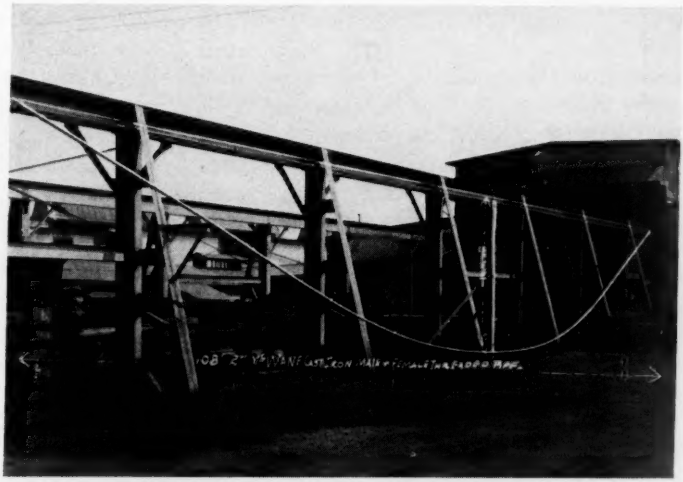
Each year the use of small-diameter cast-iron pipe is becoming more and more popular among water works distribution men. During the year 1939, more than 4,000,000 ft. of 2-in. cast-iron pipe was sold and installed in water systems throughout the country; whereas, 10 years ago the yearly sale of this kind of pipe for all purposes amounted to less than 700,000 ft. There are many reasons for this increasing use; chiefly, they are the unsatisfactory experience of water works engineers with non-corrosion-resisting metal and weak-composition piping, mounting maintenance costs on small lines, and the desire to standardize on all essential materials. Cast-iron distribution pipe in the larger sizes has been standard material in American water works systems for well over a hundred years. With improvements in joints and manufacturing methods, it has been made practicable to use 2-in. cast-iron mains. The same sound practice of water works engineers, in using cast-iron pipe for large main distribution, holds equally true for 2-in. pipe. It is good economy and engineering practice.

A great many water works systems, both municipal and privately owned, serving cities up to half a million population, have 15% to 25% of 2-in. pipe in their total distribution pipe mileage. The largest percentage of this pipe is of non-corrosion-resisting metal, which results in top-heavy maintenance costs and constant replacements. Yearly renewals of 4-in. and larger cast-iron mains are unheard of. The use of 2-in. cast-iron mains, instead of inexpensive substitute materials, greatly reduces maintenance and renewal costs on small mains.

It is conceded that 2-in. pipe is inadequate for fire-protection service, but by adoption of the duplicate-main system and tie-ins between blocks in outlying residential areas, the fire-protection problem can be taken care of with the installation of fire plugs on 6-in. and

*McWane Cast Iron Pipe Company, Birmingham, Ala.

larger mains on the principal streets. The domestic consumers on the 2-in. line can still enjoy fire-protection service and low insurance rates and comply with the Fire Underwriters regulations in not being more than 500 ft. distant from a fire hydrant. Experience has shown



TWO-INCH CAST-IRON PIPE WILL BEND.

that a 2-in. main will satisfactorily serve from 10 to 12 domestic consumers on a line 1,000 to 1,200 ft. long. The quality of this service is tremendously enhanced in planned suburban sections, where blocks run from 400 to 600 ft., and in some rare cases to 800 ft. in length when the small mains are tied into the large feeder mains at street intersections. This practice of tie-in, or gridironing, gives constant circulation and improves volume and pressure conditions as well.

There is a mistaken impression among many water works engineers that the duplicate-main system in suburban areas is an expensive luxury. An analysis of cost figures in almost any city will definitely prove the economy as well as the many advantages of the two-main system, using 6-in. and larger cast-iron mains on one side of the street and a 2-in. cast-iron main on the opposite side of the street, in the park area between sidewalk and curbing, where practical. As a matter of fact, the saving in a two-main system is largely

effected by the elimination of 75% of the service-pipe footage. The following comparison of cost figures on one-main and two-main systems are conservative. The figures are based on two 600-ft. blocks; streets 50 ft. in width, with concrete or concrete base and bitumastic top-dressing pavement; 50-ft. lots; and 60 ft. from lot line to lot line.

Estimated Cost *One-Main System*		Estimated Cost *Two-Main System*	
1250 ft.—6 in. C.I. B&S Pipe Installed @ $1.50 per ft...	$1,875.00	1250 ft.—6-in. C.I. B&S Pipe Installed @ $1.50 per ft...	$1,875.00
48—¾-in. copper service lines 30 ft. long. Installed @ 40c per ft. including curb cock and box and corporation cock @ $18.50 each	$888.00	1350 ft.—2-in. C.I. B&S Pipe Installed @ 50c ft.	$675.00
		48—¾-in. copper service lines; 5 ft. long, installed @ 40c per ft. including curb cock and box and corporation cock @ $8.50 each	$408.00
48—Service trenches of 25 ft., cutting and replacing paving @ $4.50 per sq. yd. @ $6.30 each	$302.40	150 ft.—2-in. cross street cut, ting, replacing paving @ $4.50 per sq. yd.	$37.50
		4—2-in. valves	$38.00
		2—6x6x2-in. tees	$16.00
		2—2x2x2-in. tees	$4.50
Total	$3,065.40	Total	$3,054.00

It will be noted that these costs are comparable for the one-main and two-main systems. In addition, the two-main system presents the following outstanding advantages over the one-main system:

1. It does away with a great majority of all trenches, ridges and other irregularities which mar paved streets and cause danger and discomfort to motorists.
2. It eliminates many traffic tie-ups, interruptions, and detours due to laying, extending, replacing or repairing water mains under paved streets.
3. It saves money for property owners; not only before streets are laid, but afterwards, for it lowers taxes made necessary by street repairs caused by pipe operations.
4. It eliminates the money wasted by installing unused service connections.
5. It gives additional main capacity.
6. It usually offers a lower first cost except in the case of very narrow streets.
7. It guarantees a lower maintenance cost in every case.
8. It prevents delay in paving due to waiting for trenches to settle.
9. It insures better fire protection.
10. It minimizes the hazard of damage to mains from electrolysis and vibration due to traffic.

Where the suburban area is laid out with parallel principal thoroughfares, not more than 600 ft. apart, an even greater saving can be effected by piping the secondary streets between thoroughfares with 2-in. cast-iron mains on both sides of the street. In spite of the evident economies of the two-main system for suburban sections, we sometimes hear water works men say that even so, 2-in pipe is still too small for distribution mains. The most effective way to overcome an argument of this kind is with facts. Assuming that a 6-in. main on one side of the street is operating under a pressure of 60 lb. per sq. in., that the street width is 50 ft., that the block is 600 ft. long; and that using a 2-in. main on the opposite side of the street with tie-ins at each intersection would require 700 ft. of pipe. This line would feed from both ends. Assuming that the 2-in. line supplies eight domestic consumers, it may readily be shown by the use of a simple formula in hydraulics, that each consumer would have available at least 30 g.p.m. of water, even if all eight consumers were using water at the same time. This is certainly an adequate domestic supply.

Now that the serviceability of a 2-in. pipe is proven for domestic water distribution, the selection of material is most important. It is certainly not necessary to make out a case for cast-iron pipe, as this was done many generations ago. The development of cast-iron pipe for water began in the 15th century, and 2-in. pipe was among the early sizes manufactured. So, there is nothing radically new in the use of this pipe. What is new, however, is modern manufacturing methods involving iron and sand control, mechanical equipment, and straight-line, continuous production. This has greatly reduced the cost and improved the quality and strength of 2-in. cast-iron pipe.

Innovations developed in recent years have increased the use and availability of 2-in. cast-iron pipe, so that today it comes within the budget requirements of any water works distribution plant. A complete line of small fittings and reducing fittings is now obtainable. Tees and crosses reducing on the outlet, such as 6 in. by 2 in. and 8 in. by 2 in. tees, make it a simple matter to connect 2-in. cast-iron pipes to existing mains, and also facilitate their installation in new suburban sections along with larger diameter pipe. Two-inch cast-iron pipe is now cast in 9-ft. lengths; whereas, formerly it was only possible to obtain this size in 5- and 6-ft. lengths. Each 9-ft. length is equipped with two tapping collars, which simplifies making service connections to the small main. By using these collars, 2-in. cast-iron

pipe can be tapped under pressure with a standard Mueller Type B tapping machine. This is not possible with other piping without the use of clamps.

Among the most outstanding features in the development of 2-in. cast-iron pipe is the improvement and perfection of joints. The water works engineer has a wide selection of joints, depending upon local conditions and individual preference. The bell and spigot joint is the same as that on large-diameter pipe and can be made up during construction with hot lead or a sulphur compound. The factory-made, prepared joints are the improved precalked joints, made with lead and California Redwood tongue-and-grooved wedges. As a joint-packing material, the Redwood wedges are far superior to water main jute or oakum, because the Redwood will not rot and disintegrate. The Glantite mechanical, rubber-ring joint is made with a rubber gasket upon which pressure is applied by means of a heavy gland that screws into the bell of the pipe; the gasket being firmly compressed against the inner bell gasket seat and the spigot end of the pipe. The Male & Female Threaded Joint is made by putting an oversize 2½-in. female thread in the pipe bell, and a 2½-in. male thread on the spigot end of the pipe. The pipe is equipped with hex wrench grips behind the pipe bell and on the spigot end just ahead of the male thread. All four of these joints are successfully used in water works distribution systems.

Two-in. cast-iron pipe is usually shipped in 18-ft. lengths. This length is made up at the foundry by screwing together two 9-ft. lengths, with an oversize 2½-in. male and female thread. The assembled 18-ft. length is air tested under a pressure of 90 lb. per sq. in., while the pipe is submerged in water. The high tensile, transverse, and beam strength, or ability to bend, is best illustrated in the accompanying picture of a 2-in. cast-iron pipe line 108 ft. long. This line is made up of 2½-in. male and female threaded rigid joints at 9-ft. intervals and shows a deflection of 15 ft. in the center.

In addition to the mechanical and structural features just cited, it is well to point out that 2-in. cast-iron pipe, due to its long life and small yearly depreciation percentage, strengthens the capital structure of a water plant. In the case of private utilities, this is an important consideration, as it gives them a rate-making advantage which they would not enjoy with short-lived non-corrosion-resisting metal and weak-composition pipe. The importance of this is evident in a system that counts 15% to 25% of its total distribution pipe mileage in the 2-in. size.

INDEX TO THE TRANSACTIONS AND JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1882 TO 1939.

TRANSACTIONS, 1883 TO 1885, JOURNAL, VOLUMES I TO LIII, 1886 TO 1939.

Within a year of its formation in 1882, the New England Water Works Association issued an official publication. For the years 1883, 1884 and 1885 it published its Transactions, a volume for each year. The JOURNAL was established in 1886. The quarterly issues of the first two volumes were paged separately, but beginning with Volume III the paging was made consecutive within each volume. Volumes I to XV began with the September issue. In order to conform to the calendar year, later volumes were made to begin with the March issue, Volume XV (1900-1901) containing six issues to permit this change.

The first comprehensive Index to the Transactions and JOURNAL of the Association was issued in 1904, the second in 1916, the third in 1931. The present Index is the fourth to be compiled and carries through Volume LIII, 1939; it forms part of the September JOURNAL, LIV, 1940.

The Index comprises three sections: a Subject Index, an Author Index and an Index to Affairs of the Association. The great expansion of the JOURNAL with time has made it necessary to forego reference to detailed subject matter found within papers but covered by a more comprehensive title. It has required, furthermore, that cross-referencing be limited to topics rather than papers.

The Subject Index contains a classification of papers, topical discussions, and reports of technical committees of the Association. The titles to these are given substantially as printed in the JOURNAL. A small group of papers not related to water-works matters is classified under "Miscellaneous."

The Author Index lists all papers published over an author's name, lengthy titles being abridged and obscure titles being reworded.

Under Association Affairs are classified biographical notices and portraits, non-technical committee reports and matters of general in-

terest to the Association. Proceedings of meetings including reports of officers and standing non-technical committees are not indexed since they appear regularly in each volume. Presidential addresses, likewise, are not indexed unless they are confined to a specific technical subject. In that case they appear in the Subject and Author Indexes.

Throughout the Index the volume of the JOURNAL appears in small Roman numerals, the page in larger Arabic numerals and the year in Arabic numerals within parentheses. The page number indicates the first page of the article. The three volumes of Transactions are identified by including the abbreviation "Trans." in the parentheses enclosing the year of publication. The separately paged quarterly issues of Volumes I and II are identified by interpolating the month of issue between the volume number and page number. In the Subject Index the topic is printed in bold-faced type and the author's name is given in parentheses. Discussions of papers are not indicated separately as they are more or less regular in occurrence. In the Author Index the author's name appears in bold-faced type above the titles of his papers. The subject matter of the Index to Association Affairs is printed in bold-faced type.

GORDON M. FAIR,
Editor.

Cambridge, Mass.
August 31, 1940.

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BOOK REVIEW

PUBLIC WATER SUPPLIES. By F. E. Turneaure, Emeritus Dean of the College of Engineering, and H. L. Russell, Director of Alumni Research Foundation, University of Wisconsin. Fourth edition, revised. xvi+704 pages. 6 by 9. 232 figures. Cloth. $6.00. John Wiley and Sons, Inc., New York.

Those of us who have spent a score of years or more in the water-works profession will greet the revision of this classic in water-works literature as an old friend, long absent; while younger men will profit by their new acquaintance. Although the new book is shorter by 62 pages and contains 68 figures less than the previous edition of 1924, it is by no means a streamlined version of its former self but still the meaty tome that challenged the jaws of our minds as undergraduates and practising engineers.

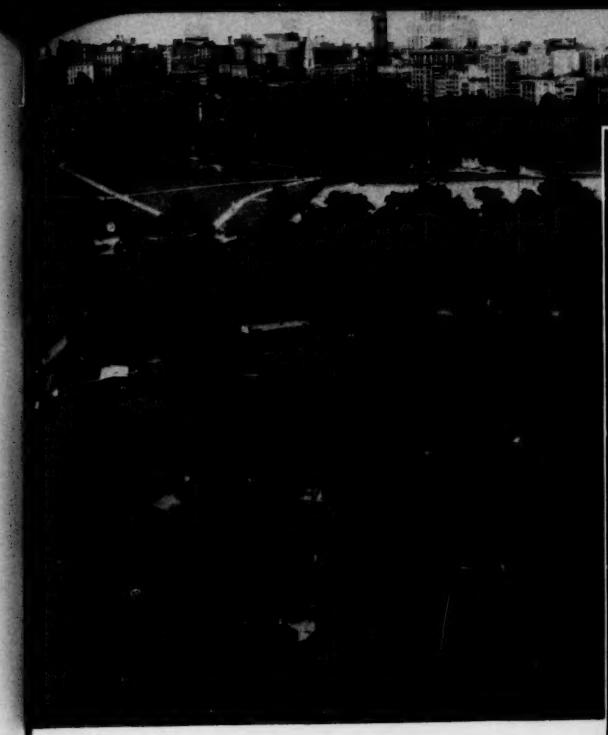
This fourth edition of Public Water Supplies is a revision in the true sense of the word. It is a good book brought to date by noting progress in principle and method and by adding information culled from recent experience. On the whole, the revision is conservative. Excepting where new collaborators were invited to be active, the revision seems to have been accomplished by the judicious use of shears and paste, *i.e.* by resection and grafting. The most notable changes have been wrought by Dr. M. Starr Nichols, Professor of Sanitary Chemistry, University of Wisconsin, and Chief Chemist, Wisconsin State Laboratory of Hygiene. Dr. Nichols has rewritten the three chapters on Quality of Water Supplies, and their authority and modernity will be appreciated. Dr. Nichols has aided also in the revision of the five chapters on Water Purification, the last of which includes many of the newer concepts in water treatment: recarbonation, hexametaphosphate, zeolites, fluorides, corrosion control, ammoniation, and activated carbon. The chapter on Pumping Machinery has been revised largely by Professor Arno T. Lenz, University of Wisconsin. It reflects modern practise to good purpose.

After an introductory chapter which presents the history, value, and importance of public water supplies, the book is divided into two parts: Part I—Requirements and Resources, and Part II—The Con-

struction of Water Works. Part I falls into two sections: A. Quantity of Water Required: Sources of Supply, made up of six chapters, four of which deal with hydrological matters; and B. Quality of Water Supplies, three chapters. Part II is subdivided directly into nineteen chapters. Single chapters on generalities pertaining to water-works construction and on hydraulics are followed by six chapters on collecting works for surface and ground waters, including three chapters on dams. Then come five chapters on water purification, two chapters on pipes and conduits, a chapter on pumping machinery, two chapters on distributing systems, and the concluding chapter on operation and maintenance. An index of ten pages, like its predecessors too brief for lazy minds, completes the book.

The book is well printed and sturdily bound. The illustrations are well chosen and, as a rule, clear. Occasionally, a long-used cut arouses the reader's nostalgia for the simpler ways of the Victorian era.

GORDON M. FAIR.



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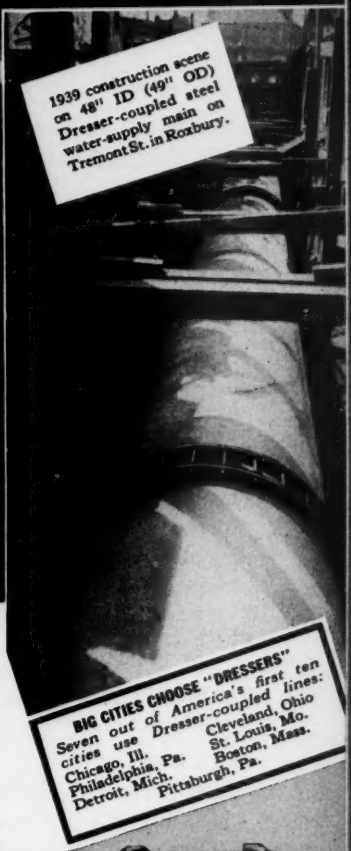

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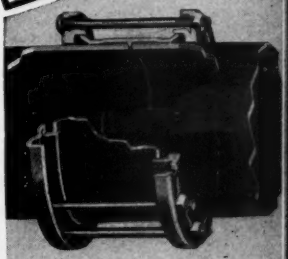

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